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Integrated Twin-Guide Corner Reflector Lasers with Surface-Grating-Etching for Simple Mode Selectivity

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1. Introduction

Integrated twin-guide (ITG) structure has been studied for applications to opto-electronic integrated circuits (OEIC's). Nowadays, metal-organic chemical vapor deposition (MOCVD) can give precise epitaxy controllability and very high uniformity by using *in situ* monitoring techniques [1]. In addition to the epitaxy, the dry etching techniques, such as reactive ion etching (RIE), or reactive ion-beam etching (RIBE), have been also well developed for compound semiconductors [2,3].

The advantages of ITG lasers with corner reflectors (CR's) are like followings: 1) it has a flexibility of bending the output light to any direction; 2) This ITG structure with CR's can be laser diode, detector and external modulator; 3) it's possible to integrate these devices with different functions on the network of waveguides for complex OEIC's [4].

In this work, we have first proposed ITG lasers that have CR's and surface-grating-etching (SGE) structure for simple wavelength selectivity. The main advantages of this ITG-CR-SGE lasers are cost reduction and simplicity of fabrication process, compared to distributed bragg reflector (DBR) lasers. And also, multiple wavelength laser source can be realized for wavelength division multiplexing (WDM) optical fiber network by integrating several ITG-SGE lasers on the same passive waveguide.

2. Design and Analysis of ITG-SGE Lasers

Lasing light is coupled to the passive output waveguide below the active layer by evanescent coupling. Normal-mode calculation was utilized for design optimization, which is well known to be an accurate method for a strongly coupled waveguide problem. First, ITG-SGE lasers are modeled to have two propagation modes in the cavity and single guide mode in passive waveguide layer , as shown in Fig. 1(a) [5]. InGaAs-AlGaAs-GaAs materials were considered for ITG-SGE lasers at λ=980 *nm*. The material parameters were calculated from Afromowitz' formula [6]. The twin-guide structure was designed so that the maximum coupling efficiency could be about 99 % with a 93.5 μm of coupling length.

Transfer matrix method was applied to describe the lasing condition in ITG-SGE lasers. Threshold gain curve could be obtained as a function of wavelength. The lowest threshold

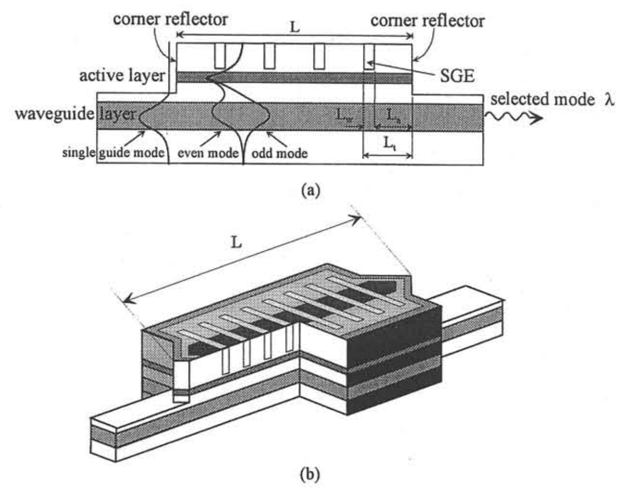

Fig. 1 (a) Propagation modes in ITG structure and wavelength selection by SGE. (b) Its 3-demensional schematic view.

gain points are the selected wavelength, which are dependent on the lengths of SGE (L_w) and microcavity (L_a). We assumed that the reflectivity of CR's was about 0.5 [2]. Fig. 2 shows simulated results of single mode selection for a properly designed ITG-SGE laser with L_w=15 μm and L_a=4.8 μm, and illustrates that the process variation of the lengths of L_w and L_a, can't affect the selected wavelength. The major mode spacing, $\Delta\lambda_{major}$=64.7 Å, varies according to the inverse of the microcavity length (L_t). It is possible to select wavelength by adjusting L_w and L_a.

We also investigated the dependency of wavelength on the ITG layer thickness variation. The wavelength fluctuation at a fixed SGE length were shown in Fig. 3.

3. Fabrication and Results

A strained InGaAs/AlGaAs/GaAs GRINSCH single quantum well laser with passive output waveguide was grown in AIXTRON 200 low-pressure MOCVD with a tailored reactor for *in situ* laser reflectometry with which we could obtain growth thickness accuracy within ± 1% error [1]. The ITG laser structure consisted of following layers: a 1-μm GaAs buffer, a 1.2-μm $Al_{0.5}Ga_{0.5}As$ lower cladding, a 527-nm $Al_{0.26}Ga_{0.74}As$ waveguide, a 550-nm $Al_{0.5}Ga_{0.5}As$ separation, a 70-Å $In_{0.2}Ga_{0.8}As$ active layer surrounded by 1500-Å $Al_xGa_{1-x}As$ graded index layers and 100-Å GaAs barrier

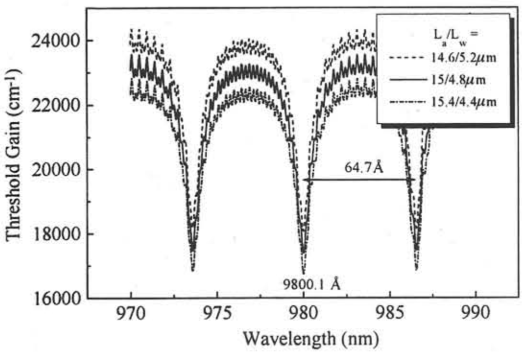

Fig. 2 Calculation result of threshold gain shows mode selectivity.

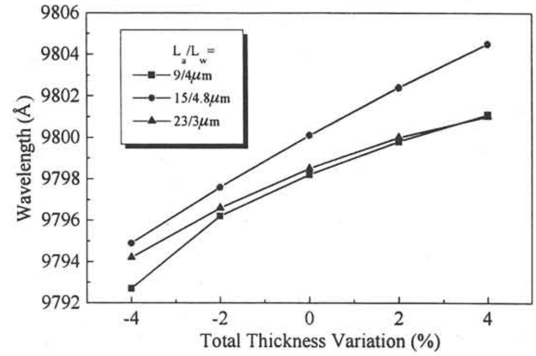

Fig. 3 Selected wavelength shifts by ITG layer thickness fluctuation.

layers, a 1.2-μm $Al_{0.5}Ga_{0.5}As$ upper cladding, and a 2000-Å GaAs ohmic contact layer.

SiO2/Ti/NiCr (2000 Å/ 300 Å/ 1000 Å) was deposited first by E-beam evaporator as a current blocking layer and also a dry-etch masking material. The cavity length (L), in Fig. 1, was selected to be about 280 μm at which the coupling efficiency of this ITG structure had a maximum value, and the cavity width was 20 μm.

First RIBE was performed in Ar/Cl_2 gas mixture at 1000eV ion source power for dry-etching of CR's and SGE's above the active layer. Complete CR's were formed by second RIBE while protecting SGE's with photoresist. To precisely control the etching depth with 100 Å resolution, etching process was also monitored by *in situ* laser reflectometry.

Planarization process with polyimide was followed by current injection strip opening process. After p-ohmic metal evaporation, the output waveguides outside the cavity were formed by chemical-etching technique. The backside was lapped and n-ohmic metal was evaporated.

The lasers were treated at the end of passive output waveguide to be suppress back reflection of light at these facets. Fig. 4 shows the optical power spectrum of an ITG-SGE laser. It demonstrates single longitudinal mode operation while ITG lasers without SGE usually operate with multiple longitudinal modes at 980 nm. The peak emission wavelength is at 933.4 nm, which doesn't correspond to ITG laser wavelength. We believe that the center wavelength of the ITG-SGE laser was shifted by the effect of short microcavity resonance [7].

4. Conclusion

We have newly proposed the integrated twin-guide lasers with corner reflectors. We have also designed and fabricated ITG-CR lasers with surface-grating-etching to gain simple wavelength selectivity. This laser operated in single longitudinal mode as we expected. The ITG-SGE lasers are promising for implementation to multi-functional OEIC's and WDM optical communication networks.

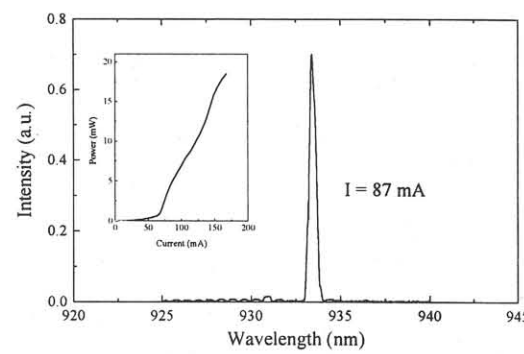

Fig. 4 Optical power spectrum characteristic of an ITG-SGE laser through passive output waveguide at room temperature. Inset : L-I curve.

Acknowledgments

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